

## CLAIMS

What is claimed:

1. A method of fabricating a semiconductor device, having a copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, comprising the steps of:  
 providing a semiconductor substrate having a Cu surface;  
 providing a chemical solution;  
 electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy thin film on the Cu surface;  
 rinsing the Cu-Zn alloy thin film in a solvent;  
 drying the Cu-Zn alloy thin film under a gaseous flow; and  
 completing formation of the semiconductor device.
2. A method, as recited in Claim 1,  
 wherein the chemical solution is nontoxic and aqueous, and  
 wherein the chemical solution comprises:  
 at least one zinc (Zn) ion source for providing a plurality of Zn ions;  
 at least one copper (Cu) ion source for providing a plurality of Cu ions;  
 at least one complexing agent for complexing the plurality of Cu ions;  
 at least one pH adjuster; and  
 at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.
3. A method, as recited in Claim 1,  
 wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate ((CH<sub>3</sub>CO<sub>2</sub>)<sub>2</sub>Zn), zinc bromide (ZnBr<sub>2</sub>), zinc carbonate hydroxide (ZnCO<sub>3</sub>·2Zn(OH)<sub>2</sub>), zinc dichloride (ZnCl<sub>2</sub>), zinc citrate ((O<sub>2</sub>CCH<sub>2</sub>C(OH)(CO<sub>2</sub>)CH<sub>2</sub>CO<sub>2</sub>)<sub>2</sub>Zn<sub>3</sub>), zinc iodide (ZnI<sub>2</sub>), zinc L-lactate ((CH<sub>3</sub>CH(OH)CO<sub>2</sub>)<sub>2</sub>Zn), zinc nitrate (Zn(NO<sub>3</sub>)<sub>2</sub>), zinc stearate ((CH<sub>3</sub>(CH<sub>2</sub>)<sub>16</sub>CO<sub>2</sub>)<sub>2</sub>Zn), zinc sulfate (ZnSO<sub>4</sub>), zinc sulfide (ZnS), zinc sulfite (ZnSO<sub>3</sub>), and their hydrates.

4. A method, as recited in Claim 1,  
 wherein the chemical solution further comprises at least one complexing agent for  
 complexing the plurality of Zn ions being dissolved in the volume of DI  
 water,  
 wherein the at least one complexing agent for complexing the plurality of Zn ions  
 comprises tartaric acid ( $\text{HO}_2\text{CCH}(\text{OH})\text{CH}(\text{OH})\text{CO}_2\text{H}$ ), and  
 wherein the tartaric acid prevents precipitation of the plurality of Zn ions from the  
 chemical solution.
5. A method, as recited in Claim 1,  
 wherein the at least one copper (Cu) ion source comprises at least one copper salt  
 selected from a group consisting essentially of copper(I) acetate  
 $(\text{CH}_3\text{CO}_2\text{Cu})$ , copper(II) acetate  $((\text{CH}_3\text{CO}_2)_2\text{Cu})$ , copper(I) bromide  $(\text{CuBr})$ ,  
 copper(II) bromide  $(\text{CuBr}_2)$ , copper(II) hydroxide  $(\text{Cu}(\text{OH})_2)$ , copper(II)  
 hydroxide phosphate  $(\text{Cu}_2(\text{OH})\text{PO}_4)$ , copper(I) iodide  $(\text{CuI})$ , copper(II)  
 nitrate hydrate  $((\text{CuNO}_3)_2)$ , copper(II) sulfate  $(\text{CuSO}_4)$ , copper(I) sulfide  
 $(\text{Cu}_2\text{S})$ , copper(II) sulfide  $(\text{CuS})$ , copper(II) tartrate  $((\text{CH}(\text{OH})\text{CO}_2)_2\text{Cu})$ , and  
 their hydrates.
6. A method, as recited in Claim 1,  
 wherein the at least one complexing agent for the plurality of Cu ions comprises at  
 least one species selected from a group consisting essentially of ethylene  
 diamine "EDA"  $(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)$  and ethylenediaminetetraacetic acid  
 "EDTA"  $((\text{HO}_2\text{CCH}_2)_2\text{NCH}_2\text{CH}_2\text{N}(\text{CH}_2\text{CO}_2\text{H})_2)$ , and  
 wherein the at least one complexing agent for the plurality of Cu ions prevents  
 precipitation of the plurality of Cu ions from the chemical solution.
7. A method, as recited in Claim 1,  
 wherein the at least one pH adjuster comprises at least one pH-adjusting compound  
 selected from a group consisting essentially of ammonium hydroxide  
 $(\text{NH}_4\text{OH})$  and tetramethylammonium hydroxide "TMAH"  $((\text{CH}_3)_4\text{NOH})$ .

8. A method, as recited in Claim 1,  
wherein the at least one wetting agent comprises a surfactant, and  
wherein the surfactant comprises at least one material selected from a group  
consisting essentially of RE-610™ and polyethylene glycol (PEG).
9. A method, as recited in Claim 1,  
wherein the Cu surface is formed by a process selected from a group consisting  
essentially of chemical vapor deposition (CVD), plasma vapor deposition  
(PVD), plasma enhanced chemical vapor deposition (PECVD),  
electroplating, and electroless plating,  
wherein said solvent comprises water, and  
wherein said gaseous flow comprises gaseous nitrogen (GN<sub>2</sub>).
10. A method, as recited in Claim 1,  
wherein the at least one zinc (Zn) ion source is provided in a concentration range of  
approximately 5 g/L to approximately 25 g/L,  
wherein the at least one complexing agent for complexing the plurality of Zn ions is  
provided in a concentration range of approximately 10 g/L to approximately  
30 g/L,  
wherein the at least one copper (Cu) ion source is provided in a concentration range  
of approximately 5 g/L to approximately 25 g/L,  
wherein the at least one complexing agent for complexing the plurality of Cu ions is  
provided in a concentration range of approximately 40 g/L to approximately  
100 g/L,  
wherein the at least one pH adjuster is provided in a concentration range of  
approximately 10 g/L to approximately 20 g/L,  
wherein the at least one wetting agent is provided in a concentration range of  
approximately 0.01 g/L to approximately 0.1 g/L, and  
wherein the volume of water is provided in a volume range of up to and including  
1 L,  
wherein the at least one pH adjuster adjusts the chemical solution to a pH in a range  
of approximately 7.5 to approximately 14,

wherein the chemical solution is maintained at a temperature in a range of approximately 16°C to approximately 35°C,  
 wherein the Cu surface is immersed for a time duration in a range of approximately 15 seconds to approximately 120 seconds,  
 wherein the Cu-Zn alloy thin film is formed having a thickness in a range of approximately 10 nm to approximately 200 nm, and  
 wherein the formed Cu-Zn alloy thin film is Zn content in a concentration range of approximately 0.10 atomic % to 1 atomic %.

11. A semiconductor device, having a copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, fabricated by a method comprising the steps of:  
 providing a semiconductor substrate having a Cu surface;  
 providing a chemical solution;  
 electroplating the Cu surface in the chemical solution, thereby forming a Cu-Zn alloy thin film on the Cu surface;  
 rinsing the Cu-Zn alloy thin film in a solvent;  
 drying the Cu-Zn alloy thin film under a gaseous flow; and  
 completing formation of the semiconductor device.
12. A device, as recited in Claim 11,  
 wherein the chemical solution is nontoxic and aqueous, and  
 wherein the chemical solution comprises:  
 at least one zinc (Zn) ion source for providing a plurality of Zn ions;  
 at least one copper (Cu) ion source for providing a plurality of Cu ions;  
 at least one complexing agent for complexing the plurality of Cu ions;  
 at least one pH adjuster; and  
 at least one wetting agent for stabilizing the chemical solution, all being dissolved in a volume of deionized (DI) water.

13. A device, as recited in Claim 11,

wherein the at least one zinc (Zn) ion source comprises at least one zinc salt selected from a group consisting essentially of zinc acetate  $((\text{CH}_3\text{CO}_2)_2\text{Zn})$ , zinc bromide  $(\text{ZnBr}_2)$ , zinc carbonate hydroxide  $(\text{ZnCO}_3 \cdot 2\text{Zn}(\text{OH})_2)$ , zinc dichloride  $(\text{ZnCl}_2)$ , zinc citrate  $((\text{O}_2\text{CCH}_2\text{C}(\text{OH})(\text{CO}_2)\text{CH}_2\text{CO}_2)_2\text{Zn}_3)$ , zinc iodide  $(\text{ZnI}_2)$ , zinc L-lactate  $((\text{CH}_3\text{CH}(\text{OH})\text{CO}_2)_2\text{Zn})$ , zinc nitrate  $(\text{Zn}(\text{NO}_3)_2)$ , zinc stearate  $((\text{CH}_3(\text{CH}_2)_{16}\text{CO}_2)_2\text{Zn})$ , zinc sulfate  $(\text{ZnSO}_4)$ , zinc sulfide  $(\text{ZnS})$ , zinc sulfite  $(\text{ZnSO}_3)$ , and their hydrates.

14. A device, as recited in Claim 11,

wherein the chemical solution further comprises at least one complexing agent for complexing the plurality of Zn ions being dissolved in the volume of DI water, wherein the at least one complexing agent for complexing the plurality of Zn ions comprises tartaric acid  $(\text{HO}_2\text{CCH}(\text{OH})\text{CH}(\text{OH})\text{CO}_2\text{H})$ , and wherein the tartaric acid prevents precipitation of the plurality of Zn ions from the chemical solution.

15. A device, as recited in Claim 11,

wherein the at least one copper (Cu) ion source comprises at least one copper salt selected from a group consisting essentially of copper(I) acetate  $(\text{CH}_3\text{CO}_2\text{Cu})$ , copper(II) acetate  $((\text{CH}_3\text{CO}_2)_2\text{Cu})$ , copper(I) bromide  $(\text{CuBr})$ , copper(II) bromide  $(\text{CuBr}_2)$ , copper(II) hydroxide  $(\text{Cu}(\text{OH})_2)$ , copper(II) hydroxide phosphate  $(\text{Cu}_2(\text{OH})\text{PO}_4)$ , copper(I) iodide  $(\text{CuI})$ , copper(II) nitrate hydrate  $((\text{CuNO}_3)_2)$ , copper(II) sulfate  $(\text{CuSO}_4)$ , copper(I) sulfide  $(\text{Cu}_2\text{S})$ , copper(II) sulfide  $(\text{CuS})$ , copper(II) tartrate  $((\text{CH}(\text{OH})\text{CO}_2)_2\text{Cu})$ , and their hydrates.

16. A device, as recited in Claim 11,

wherein the at least one complexing agent for the plurality of Cu ions comprises at least one species selected from a group consisting essentially of ethylene diamine "EDA"  $(\text{H}_2\text{NCH}_2\text{CH}_2\text{NH}_2)$  and ethylenediaminetetraacetic acid "EDTA"  $((\text{HO}_2\text{CCH}_2)_2\text{NCH}_2\text{CH}_2\text{N}(\text{CH}_2\text{CO}_2\text{H})_2)$ , and

wherein the at least one compelling agent for the plurality of Cu ions prevents precipitation of the plurality of Cu ions from the chemical solution.

17. A device, as recited in Claim 11,

wherein the at least one pH adjuster comprises at least one pH-adjusting compound selected from a group of consisting essentially of ammonium hydroxide ( $\text{NH}_4\text{OH}$ ) and tetramethylammonium hydroxide "TMAH" ( $(\text{CH}_3)_4\text{NOH}$ ).

18. A device, as recited in Claim 11,

wherein the at least one wetting agent comprises a surfactant, and wherein the surfactant comprises at least one surfactant selected from a group of surfactants consisting essentially of RE-610™ and polyethylene glycol (PEG).

19. A device, as recited in Claim 11,

wherein the Cu surface is formed by a process selected from a group consisting essentially of chemical vapor deposition (CVD), plasma vapor deposition (PVD), plasma enhanced chemical vapor deposition (PECVD), electroplating, and electroless plating, wherein said solvent comprises water, and wherein said gaseous flow comprises gaseous nitrogen ( $\text{GN}_2$ ).

20. A semiconductor device, having a copper-zinc alloy (Cu-Zn) thin film formed on a copper (Cu) surface by electroplating the Cu surface in a chemical solution, comprising:

a semiconductor substrate having at least one Cu surface formed thereon; and a Cu-Zn alloy thin film formed and disposed on the at least one Cu surface.